Urban-Induced Rainfall Anomalies in an Arid Regime

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Popular Summary
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Arid and semi-arid regions of the southwestern United States are rapidly developing and placing greater demands on the environmental system. Such rapid growth increases the potential impacts of human activities on the Earth's natural system. One particular system that is sensitive to human activity is the water cycle. The water cycle circuit is the source of potable water for sustaining life. At the same time, the water cycle components that sustain life are become more scarce and polluted. For example, the most recent (1999-2004) drought experienced in the southwestern United States is the seventh worst in the approximately 500-year proxy tree-ring record. As a result, many regions contemplated "drought emergencies" in which severe water restrictions are implemented

Though large-scale forcing likely controls drought processes, there is increasing evidence that anthropogenic or "human-related" activities can significantly alter precipitation processes. Urbanization is an example of anthropogenic forcing. Recent studies continue to provide evidence that urban environments can modify or induce precipitation under a specific set of conditions. In the United States, cities in the arid Southwest like Phoenix (the fourteenth largest metropolitan area according to the U.S. Census Bureau 2001) are experiencing rapid growth. In the past fifty years, Phoenix has expanded for a predominantly agricultural center to an urbanized region with extent 700 percent larger than its size in the middle of the twentieth century. Yet, few studies have examined the impact of semi-arid and arid cities on precipitation processes.

The study employs a unique 108-year precipitation data record to identify statistically significant anomalies in rainfall downwind of the Phoenix, Arizona urban region. Our analysis reveals that during the monsoon rainfall season (July, August, September) locations in the northeastern suburbs and exurbs of the Phoenix metropolitan urban area (the so-called "anomaly region") have experienced statistically significant increases in mean precipitation of 12 to 14 percent from a pre-urban (1895-1949) to post-urban (1950-2003) period. Additionally, mean and median post-urban precipitation totals in the anomaly region are significantly greater, in the statistical sense, than regions west of the city and in nearby mountainous regions of similar or greater topography. Further analysis of satellite-based rainfall totals for the summer of 2003 also reveal the existence of the anomaly region even though the arid southwest experienced severe drought during the period. More significant mountain features do not correspond to the location of the anomaly region, and statistically significant precipitation changes are found in the anomaly region when pre- and post- urban data are analyzed. Thus, it is hypothesized that mesoscale and microphysical processes related to anthropogenic forcings (urban land use and/or aerosols) interact with the topographic circulations in the region to establish the precipitation anomaly though further modeling studies will be needed to test the hypothesis.